

OUTLINE FOR THE APPLICATION FOR EXEMPTION TO CONTINUE
INJECTION OF BANNED HAZARDOUS WASTE
November 3, 1994

I. Administrative

A. Applicant:

1. Facility name.
2. Well number(s).
3. Permit number(s).
4. Address.
5. Telephone number(s).
6. Fax number.

- B. Authority: Person(s) or firm(s), including complete mailing address and telephone and fax numbers, authorized to act for the applicant during the processing of this application.

C. Nature and status of activity

1. The petitioner should include within the executive summary, a complete description of the specifics requested in the petition (i.e. waste codes, specific gravity range, injection intervals, date of end of operations, injection rates, etc.)
2. Type of operation or process that generates injection fluids: (for example, sulfuric acid plant, petro-chemical plant, sewage treatment plant, etc.).

D. Injection well(s)

1. Well number(s).
2. UIC permit number(s).
3. Location description: (county, parish, survey, section, township and range, latitude and longitude, etc.).

4. Surrounding land usage (e.g. farm, industry, etc.).

E. Injection activity

1. Depths, thicknesses and geologic names of:
Injection Interval
Injection Zone
Confining Zone
2. Permitted injection pressure(s).
3. Permitted injection rates and volumes.
4. Cumulative injected volume to date.
5. A list of all offset injection wells operating within the general area and injecting into the same injection zone.
6. A list of all offset oil and gas production from the injection zone.

F. Location Maps

1. A USGS topographic map (1:24,000 scale if available) indicating the plant boundaries.
2. A map depicting the approximate boundaries of the tract of land on which the waste disposal activity is or will be conducted. This map should also show the location of the disposal well(s) and should be of reasonable scale.
3. A map depicting the general character of the areas adjacent to the place or places of disposal such as residential, commercial, recreational, agricultural, undeveloped, etc.
4. The boundaries and ownership of tracts of land adjacent to the plant boundaries. Include with the map, a list containing the names and mailing addresses of the owners of the tracts of land adjacent to the plant boundaries keyed to the map.

G. Depth of Underground Source of Drinking Water (USDW)

H. Area of Review (AOR)

1. Cone of influence distance.
 2. The number of Artificial Penetrations (AP) that penetrate the injection zone and are within the 2.0 mile AOR.
 3. The number of APs that penetrate the injection zone and are within the 10,000 year waste plume.
- I. Radioactive Tracer Survey (RAT) and Annulus Pressure Test.
 - J. Certification of petition information [40CFR 148.22(a)(4)].
- II. Injection well(s) design, construction, monitoring and operation.
 - A. Well design(s).
 1. A schematic of each well, including perforations, casing weights, sizes, and depths, tops of cement, packer depth, etc.
 2. An SP-Resistivity trace.
 3. Significant formations delineated.
 4. The injection interval, injection zone, and confining zone delineated.
 - B. Drilling and construction history. This should include the following:
 1. Complete daily drilling log.
 2. Drill stem tests
 3. Other pressure testing (can be described in more detail in the modeling section of the outline).
 4. All open hole electric logs (resistivity, porosity, fracture identification, etc.), and all cased hole logs (cement bond, temperature, noise, etc.) run since each well was drilled.
 5. Hole size, core data, and any other testing.

Well logs should be annotated with the top of the confining zone, injection zone and injection interval, and USDW indicated.

- C. Original completion and any re-completions.
- D. Type of completion - open hole, cased and perforated, etc.
- E. Type, size, weight, grade and setting depth of all casing strings, API standards.
- F. Cementing procedures and type of cements including volumes, additives, slurry weight, etc.
- G. Size and type of tubing, packer, and packer setting depth.
- H. Describe chronologically, the operational history of the injection well(s) including problems, workovers and any remedial activity; maximum and average injection pressures; reservoir pressure increases; extent of injected fluids; mechanical integrity testing; stimulation information; step-rate tests; etc.

III. Mechanical integrity testing

- A. RAT or other approved test conducted within one year of submittal of request.
- B. Annulus pressure test.
- C. Identification of contractors, interpreters of data, state witnesses.
- D. Additional past tests may be required (i.e. temperature logs, noise logs, OALs, etc.).

IV. AOR

- A. Shallow water wells - search protocol and results.
- B. Search protocol for APs that penetrate the injection zone.
- C. Describe how the AOR was determined for the injection well(s).

- D. Non-endangerment demonstration for APs in the AOR.
- E. No migration demonstration for APs in the waste plume.
- F. Include an assessment of potential problem penetrations.
- G. Include a corrective action proposal for all potential problem APs with a time frame for remediation of problem.
- H. A piezometric map of the lowermost USDW in the AOR.
- I. A map showing the location of all APs (oil and gas wells, dry holes, disposal wells, geothermal wells, etc.). Map should be on a usable scale (1:200) and all APs should be indexed and properly labeled.
- J. A table of all wells that penetrate the injection zone within the AOR. This table should include the following:
 - 1. AP index number.
 - 2. Operator Name.
 - 3. Well number.
 - 4. Total depth.
 - 5. Date drilled.
 - 6. Well status (i.e. plugged, dry hole, etc.).
 - 7. Top of injection interval in this well.
 - 8. Is well mud filled?
 - 9. Mud data.
 - 10. Casing data (all casing strings).
 - 11. Cementing data for all casing strings.
 - 12. Cement plugs and setting depths.
 - 13. Date plugged.

14. Distance from injection well(s).
 15. Pressure buildup at this location.
- K. A table of all wells that penetrate the injection zone within the 10,000 year plume. This table should include the following:
1. AP index number.
 2. Operator Name.
 3. Well number.
 4. Total depth.
 5. Date drilled.
 6. Well status (i.e. plugged, dry hole, etc.).
 7. Top of injection interval in this well.
 8. Is well mud filled?
 9. Mud data.
 10. Casing data (all casing strings).
 11. Cementing data for all casing strings.
 12. Cement plugs and setting depths.
 13. Date plugged.
 14. Distance from injection well(s).
 15. Pressure buildup at this location.
- L. All APs that penetrate the injection zone should have well schematics outlining completion intervals, casing, cement and plugs. All well records to support the above data should be supplied (i.e. state drilling permits, completion records, plugging reports, etc.).
- V. Regional Geology
- A. A description of the regional stratigraphy and lithostratigraphic units.

- B. Depositional history.
- C. Tectonic history and discussion on structural geology including all faulting, folding, diapirism, etc.
- D. Historical seismic activity in the regional area (at least a 100 square mile area around the injection well(s)). Data should include intensity levels (using an international scale) and distances from the injection facility. A risk assessment of induced seismicity due to injection activities should be provided. This should include a known induced seismicity formula.
- E. Regional hydrogeology describing all aquifers and aquicludes.
- F. Regional structure map (including a commercially available map) on top of the injection interval (preferred), or closest available horizon, and cross-sections (north-south and east-west at a minimum) on a scale necessary to depict the regional geology of the area. Cross-sections should be annotated with USDW, confining zone, injection zone, and injection interval.

VI. Local Geology

- A. A description of the stratigraphy and lithostratigraphic units.
- B. Depositional history, if not discussed under regional geology.
- C. Specific tectonic history and discussion on structural geology including all faulting, folding, diapirism, etc. This should include detailed structure maps on the top of the:
 - 1. Confining Zone.
 - 2. Injection Zone.
 - 3. Injection Interval.

These maps should depict the AOR, operational waste plume, and 10,000 year waste plume.

- D. Surface faults and lineaments.

- E. A minimum of two structural cross-sections perpendicular to each other crossing at the well location or center of well field. These cross-sections should include available log control, geologic units and lithology indicated from the surface through the lower confining bed below the injection zone. Structural cross-sections should use sea level for the datum. Scale should be such that injection interval strata can be easily correlated. Stratigraphic cross-sections may be needed if correlation is particularly difficult. The datum for stratigraphic cross-sections should be the top of the injection interval.
- F. Confining zone:
1. Lithology and mineralogy.
 2. Areal extent of confining strata.
 3. Areal extent of bleed off strata.
 4. Fracturing or solution channeling.
 5. Faulting.
 6. Permeability.
 7. Isopach map.
- G. Injection zone:
1. Lithology and mineralogy.
 2. Areal extent of confining strata.
 3. Areal extent of permeable strata.
 4. Fracturing or solution channeling.
 5. Faulting.
 6. Permeability and porosity.
 7. Isopach map.
- H. Injection Interval:
1. Lithology and mineralogy.

2. Areal extent of permeable strata.
 3. Fracturing or solution channeling.
 4. Faulting.
 5. Permeability and porosity.
 6. Facies changes.
 7. Isopach map.
- I. Calculation of lowest USDW from electric logs or from water samples.
 - J. Hydrostatic pressure calculation at lowest USDW.
 - K. Seismic lines, if necessary, to delineate the local structure due to lack of subsurface well data at the injection interval depths.
 - L. A map indicating all available seismic coverage within the general area (if seismic data required).
- VII. Hydrogeology and geochemistry of the injection zone and confining zone
- A. Porosity, permeability, heterogeneity, and temperature.
 - B. Initial and current reservoir pressure (bottom-hole pressure) or hydrostatic head, chemical and physical characteristics of formation and formation fluids (i.e. injection zone fluid analysis, injection zone mineralogy, etc.).
 - C. Location, extent, and effects of known or suspected faulting, fracturing and/or formation solution channels.
 - D. Fracture gradient or formation breakdown pressure (show calculations and method used).
 - E. Characteristics of injected fluids and compatibility.
 1. Chemical and physical characteristics of injected fluid.
 2. Compatibility of injected fluids with:

- a. Injection zone and confining zone confining strata.
- b. Injection interval.

This section should include actual compatibility studies with wastes and core data. If such studies are impractical, a detailed demonstration using probable chemical reactions between the injectate and the formation should be made.

- 3. A discussion on how the injectate will alter the confining capability of the confining strata within the injection zone.
- 4. Corrosion analysis for well materials (including cement) in contact with injected fluids (if corrosive).

VIII. Purpose of modeling and summary of request.

IX. Discussion of numerical and analytical models used in the demonstration.

- A. Names and developers of models. Analytical equations should be properly referenced as they are employed in the demonstration.
- B. Complete reference listing.
- C. Statement of availability of models used.
- D. Physical processes addressed by the models
- E. Governing equations employed by models.
 - 1. Numerical - Presentation of basic governing equations.
 - 2. Analytical - Presentation of basic governing equations with full development of equations as they are employed.
- F. Discussion of all assumptions inherent in both the governing equations and the numerical implementation of these equations.

- G. Manner in which the numerical model solves the governing equations, and the method of code implementation.
- H. Manner in which all boundary conditions are addressed by the model(s).
- I. Discussion of verification (does the code correctly, consistently, and completely solve the governing equations?) and validation (the comparison of modeled results with independently derived data).
 - 1. Neither is necessary for models whose verification and validation have been accepted by Region 6 in the past.
 - 2. Verification is necessary for computer based analytical models.
 - 3. Neither is necessary for pure analytical models with no computer implementation (equations only).
- X. Brief discussion of the depositional and post depositional injection zone geologic environment (i.e. fluvial-deltaic, deep marine, etc.) as it relates to the following:
 - A. Continuity of the injection interval(s) and confinement zones.
 - B. Expected effect on the heterogeneity and anisotropy of the injection interval(s).
 - C. Post depositional/diagenetic effects on permeability and porosity (i.e. vugularity, dolomitization, etc.)
- XI. Discussion of the structure of the injection zone. Appropriate references to maps and other data sources should be made.
 - A. Brief discussion of the dominant regional stresses on the injection zone (i.e. salt domes, historical tectonic stresses, etc.)
 - B. Identification of the structural elements (i.e. salt domes, faults, etc.) within the injection zone that influence the models.

- C. Discussion of how the structure of the injection zone, and how the structural elements in the injection zone were integrated into the models.
 - 1. Discussion of why either a two or three dimensional model is appropriate.
 - 2. Discussion of how injection zone boundaries were incorporated into the modeling strategy.
 - 3. Discussion of fracture system, including orientation, continuity, and transmissibility.

XII. Conceptual model.

- A. General discussion of the modeling conceptualization.
- B. Discussion of all assumptions employed in the modeling conceptualization.
- C. Discussion of all processes modeled.

XIII. Injection zone parameter assignment.

- A. Parameter by parameter discussion of each data source that is employed by the model.
 - 1. Detailed presentation of all information (falloff tests, core data, logs, etc.) or calculations, including supporting information (nomographs, handbooks, papers, etc.).
 - 2. Complete discussion of data acquisition techniques such as falloff testing or core reports.
- B. Assignment of confidence levels to parameters.
 - 1. Evaluation of the data quality for each parameter.
 - 2. Establishment of parameter ranges.
- C. Establishment of worst-case parameter sets.
 - 1. Used to account for parameter uncertainty.
 - 2. Pressure buildup and waste transport models may require different worst-case parameter sets (i.e.

high transmissibility for waste transport and low transmissibility for pressure buildup).

XIV. Initial and boundary conditions.

- A. Discussion of how the initial pressure of the system was assigned.
- B. Discussion of how the initial regional ground water velocity was calculated and implemented in the models.
 - 1. Calculation of velocity through comparison of heads at recharge area and injection site.
 - 2. Assignment of velocity based on literature value.
 - 3. Incorporation of structural elements, such as sealing faults into the velocity calculation/assignment.
- C. Discussion of how the upper and lower injection interval boundaries were configured in the model.
 - 1. No flow boundaries - single layer analytical pressure buildup and waste transport models and some numerical waste transport models.
 - 2. Partially transmissive - small vertical flow due to assignment of vertical transmissivity in numerical models.
- D. Discussion of how lateral boundaries were configured in the model.
 - 1. Incorporated into the grid of numerical model.
 - 2. Use of image wells to model no flow boundaries in analytical and numerical models.

XV. Incorporation of sources and sinks.

- A. Identification of all sources (i.e. injection wells) and sinks (i.e production wells).
 - 1. Geological data presentation, such as cross-sections, demonstrating that a particular source/sink is in hydraulic communication with the injection well.

2. Presentation of ancillary information, such as historical and projected injection rates, distances from the injection well, etc.
- B. Treatment of non-point sources/sinks, such as oil fields.
1. Possible to treat oil fields as point sources if the injection well is not significantly influenced by individual wells within the field.
 - a. May be incorporated directly into the model as point sources.
 - b. Regarding waste transport models, it is possible to analytically treat the effect of oil fields as velocity vectors.
 2. In cases in which the oil fields are either very close to the injection wells, or are spread out over a large area, it may not be appropriate to treat them as point sources.
 3. Ensure that total fluid withdrawal (oil, gas, and water), including the correction for fluid expansibility, is accounted for in the models.
- C. Discussion of how the sources and sinks were incorporated into the model.
- XVI. Discussion of the construction of the numerical model, if applicable.
- A. Grid design.
1. Discussion of how the grid was generated (i.e. automatic or manual).
 2. Effect of grid block size(s) on the accuracy of the solution and the treatment of boundaries.
 - a. Use finer grid cells in the areas in which more accuracy is desired such as sinks and sources, and boundaries, or

- b. Demonstrate that a relatively coarse overall grid does not significantly change the results.
 - 3. Alignment of grid axes with regional features such as anisotropy, ground water direction, etc.
 - 4. The use of symmetry, if any, in the grid design.
 - 5. If the grid does not encompass the entire reservoir, one of the following must be satisfied:
 - a. The reservoir boundaries must be sufficiently removed from the area of interest so as not to influence the solution.
 - b. The effect of flow across the grid boundary must be accounted for through the use of one of the following:
 - i) An aquifer submodel, such as the Carter-Tracy approximation.
 - ii) Lines of opposing injection and production wells, on opposite ends of the reservoir, resulting in a fluid sweep.
- B. Choice of time steps.
 - 1. Ensure that material balance is satisfied at each time step.
 - 2. Ensure that time steps correspond to changes in input parameters, such as injection rates and density.
- C. Numerical considerations.
 - 1. Relationship between numerical accuracy, time step size, grid cell size, and solution stability.
 - a. Conformance to Peclet Number.
 - b. Conformance to Courant criterion.
 - 2. Changes in grid cell size should be done gradually to prevent numerical instability.

XVII. Modeling Strategy.

- A. Employ reasonable worst case modeling runs, where some reservoir parameters, such as transmissibility, are varied to the conservative ends of their ranges.
 - 1. The goal of worst case waste transport modeling is not accuracy, but to define an "envelope", inside of which all possible points of migration are investigated.
 - 2. The goal of worst case pressure buildup modeling is to predict a worst case pressure buildup at possible points of discharge, such as abandoned wellbores. Modeled flowing pressures should exceed measured flowing pressures.
 - 3. A worst case modeling strategy may necessitate the use of different parameter sets for the waste transport and pressure buildup modeling in which some parameters are varied to the opposite ends of their ranges.
- B. Treatment of unknowns.
 - 1. In pressure buildup modeling, faults will generally be modeled as sealing in order to increase the pressure buildup in the reservoir, unless information can be presented that indicates a particular fault is transmissive.
 - a. Presentation of geological information, such as mapping a sand-to-sand contact, is generally not sufficient to prove that a fault is transmissive, since this type of demonstration ignores near fault disturbances such as fault gouge.
 - b. The use of reservoir testing for identification of boundaries should be used with caution.
 - i. A falloff test, for instance, can only detect boundaries within its radius of investigation.
 - ii. Expertise is needed in order to distinguish true boundary signatures on

a pressure derivative plot, from other causes.

- c. Faults with a variable throw may indicate that the fault has windows of transmissiveness along its length.

2. Treatment of fractured systems.

- a. Fractured systems, mainly carbonates, can exhibit directional transmissibility due to the orientation of the fractures.
 - i. The majority of the flow may initially occur through these fractures due to the high ratio of the fracture transmissibility to that of the rock matrix.
 - ii. The presence of this type of flow regime can be detected by falloff testing, core analysis, and geologic information.
 - iii. Waste transport can be great due to the compartmentalization of the waste plume caused by the directional transmissibility, and the relatively high transmissibility of the fracture system.
- b. It may be impossible to determine the prevailing fracture orientation, since this requires data collected on a regional scale.
- c. Worst case modeling of the waste plume may necessitate the assignment of a high reservoir transmissibility, and rotation of the waste plume along arcs of possible fracture orientation.

XVIII. History matching.

- A. Most often performed by matching measured flowing pressures versus modeled bottomhole pressures.
 - 1. Must have good quality historical data.
 - 2. Ensure that the historical flowing pressures are translated to a common datum.

3. Often not appropriate to convert pressures measured at the surface to flowing bottomhole pressures, due to the usual absence of skin damage information.
- B. Unless measured pressures are available for points away from the injection well, recognize that the value of the history match is limited.
1. The modeled pressures are generated assuming that the actual reservoir geometry, structure, parameters, sources and sinks, etc. are adequately represented.
 2. Possible to obtain a match at the well and not away from the well due to changes in structure, heterogeneity, or unknown influences. This is a concern because the main purpose of the pressure buildup model is to generate pressures at points away from the well (abandoned wellbores).
- C. Obtaining a good match on a pressure buildup model does not necessarily mean that the waste transport model is calibrated.
- D. Often more productive to use worst case reservoir modeling. Demonstrate that the modeled flowing bottomhole pressures are greater than the measured pressures.

XIX. Vertical migration.

- A. The mechanisms of vertical migration through intact rock are convection, mechanical dispersion, and molecular diffusion.
1. Vertical convection should be calculated based on the maximum injection rate and the high end of the containment strata permeability.
 2. Molecular diffusion calculations should be based on Fick's Second Law, and conservative diffusivity, tortuosity, and concentration values.
 - a. The most diffusive molecules are generally those with the smallest molecular radii.

- b. The worst case molecule is that with the combination of the greatest diffusivity, and lowest concentration reduction factor.
 3. Mechanical dispersion may be significant if vertical transmissibility is relatively high.
- B. The mechanisms of vertical migration through abandoned wellbores are molecular diffusion, buoyancy, and pressure driven flow.
 1. Molecular diffusion through abandoned wellbores should be treated in the same way as with intact rock, with the exception that the tortuosity value will change.
 - a. The tortuosity value for brine is 1.0.
 - b. The tortuosity value for a mud filled wellbore may be assigned by correlating the total dissolved solids of the mud to a "porosity" value, which is in turn correlated to a tortuosity value, in the same manner as is done with a shale.
 2. A buoyant waste introduced into a brine filled abandoned wellbore is assumed to migrate vertically out of the injection zone.
 3. A buoyant waste introduced into a mud filled abandoned wellbore is not assumed to migrate vertically out of the injection zone, due to the minimal gel strength of the mud.
 4. All diffusion is assumed to take place vertically.
 5. The influence of cement plugs on diffusion is ignored.
 6. The potential for pressure driven migration through abandoned wellbores should be evaluated by comparing the potential of the reservoir with the potential of the wellbore.
 - a. This should be done at the elevation of the top of the injection interval.

- b. The potential of the reservoir should be calculated by adjusting the total pressure at the end of operations, at the location of the wellbore, for elevation effects, if any.
- c. The potential of the wellbore should be calculated by adding the pressure due to the head of fluid to the pressure resistance of the gel strength of the mud, if any. The minimum gel strength of any mud is 20 lbs/100 sq ft.

XX. Display of modeling results.

- A. A composite of all lateral waste transport modeling runs should be depicted on a structure map of the top of the injection interval for both the end of operations and the 10,000 year period. Waste transport should be shown to honor the structure.
- B. Unsymmetrical (variable transmissibility) worst case flowing pressure buildup results, at the time of greatest pressure buildup (usually the end of operations), should be displayed on a pressure isopleth map of the AOR. Symmetrical worst case flowing pressure buildup results may be displayed on an accurate Cartesian graph.
- C. Worst case bottomhole flowing pressure buildup results, at the location of the injection wellbore(s), should be plotted against time for the historical and projected operational period. Individual years should be clearly delineated. If possible, a separate tabulation of the monthly pressure buildup results should be provided. Numerically generated block pressures may need to be adjusted back to the location of the wellbore(s).
- D. Vertical waste transport and pressure buildup at the wellbore(s) may optionally be displayed on a vertical geologic section map.

XXI. Discussion of results.

Appendix A

Summary of Minimum Required Graphics

1. Earthquake location map.
2. Structure maps of the top of the confining zone, injection zone, and injection interval. Commercial structure map on the top of the injection interval (preferred) or injection zone or nearest horizon.
3. Isopach maps of the confining zone, injection zone, and each injection interval.
4. A minimum of two structural cross-sections perpendicular to each other crossing at the well location or center of well field. Stratigraphic cross-sections may be needed if correlation is particularly difficult. The datum for stratigraphic cross-sections should be the top of the injection interval.
5. All logs (except past RAT logs) for the injection wells, including all open hole electric logs (resistivity, porosity, fracture identification, etc.), and all cased hole logs (cement bond, temperature, noise, etc.) hole size, core data, and any other testing. Well logs should be annotated with the top of the confining zone, injection zone and injection interval, and USDW. In addition, a representative number of logs of wells penetrating the horizon in question (i.e. confining zone, injection zone, injection interval) should be submitted so that control points on maps can be verified.
6. A composite of all lateral waste transport modeling runs should be depicted on a structure map of the top of the injection interval for both the end of operations and the 10,000 year period.
7. Worst case flowing pressure buildup results versus distance from the well, at the time of greatest pressure buildup (usually the end of operations).
8. Worst case bottomhole flowing pressure buildup results, at the location of the injection wellbore(s) versus time for the historical and projected operational period.
9. Derivative and Horner type plots for every falloff test run since each well was drilled.

10. A drawing containing the following for each well:
 - a) A schematic of the well, including perforations, casing weights, sizes, and depths, tops of cement, packer depth, etc.
 - b) An SP-Resistivity trace.
 - c) Significant formations delineated.
 - d) The injection interval, injection zone, and confining zone.
11. A USGS topographic map (1:24,000 scale if available) indicating the plant boundaries.
 - a. A map depicting the approximate boundaries of the tract of land on which the waste disposal activity is or will be conducted. This map should also show the location of the disposal well(s) and should be of reasonable scale.
 - b. A map depicting the general character of the areas adjacent to the place or places of disposal such as residential, commercial, recreational, agricultural, undeveloped, etc.
12. The boundaries and ownership of tracts of land adjacent to the plant boundaries.
13. A piezometric map of the lowermost USDW in the AOR.
14. A map showing the location of all APs (oil and gas wells, dry holes, disposal wells, geothermal wells, etc.). Map should be on a usable scale (1:200) and all APs should be indexed and properly labeled.
15. A map indicating all available seismic coverage within the general area (if seismic data required).